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MULTIPARTICLE PRODUCTION IN HIGH-MASS DIFFRACTION DISSOCIATION AND THE INTERPLAY OF PHOTONS AND POMERONS [a]

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Multiple interaction models satisfying s-channel unitarity predict that, in contrast to inelastic processes, factorization is violated in diffractive processes. The size of this effect can be characterized in terms of the rapidity gap survival probability. The possibility of its measurement at HERA is pointed out. Furthermore a method to measure photon diffraction dissociation at LEP2 and planned linear colliders is discussed and cross section predictions are given.

1 Unitarity, pomerons, and factorization

Assuming that high virtual masses are damped due to the dynamics of the the strong interaction, hadronic interactions can be described by Gribov's Reggeon field theory (RFT)[1,2]. The total amplitude can be written as the sum of n-pomeron exchange amplitudes $A^{(n)}(s,t)$. Unitarity implies that at high energies graphs with n-pomeron exchange become important. However, it should be emphasized that only the one-pomeron exchange graph satisfies factorization as assumed, for example, in parton model calculations of hadronic jet production.

Why do we expect factorization in inclusive processes? For example, let's consider the simplest "factorization-breaking" contribution, the two-pomeron graph. To discuss particle production, we apply the optical theorem together with the AGK cutting rules[3]. Three different cut configurations are giving the dominant contributions: the diffractive cut with the weight 1 (Fig. 1 a)), the one-pomeron cut with the weight -4 (Fig. 1 b)), and the two-pomeron cut with the weight 2 (Fig. 1 c)). Assuming that a two-pomeron cut gives two times

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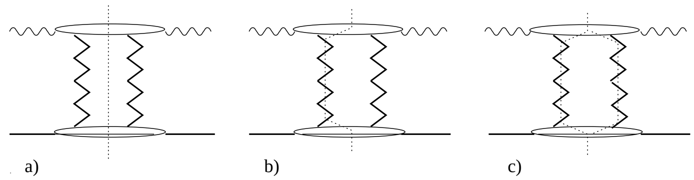

Figure 1: *Breakdown of the total discontinuity of the two-pomeron exchange graph according to the AGK cutting rules: a) the diffractive cut describing low-mass diffraction, b) the one-pomeron cut, and c) the two-pomeron cut.*

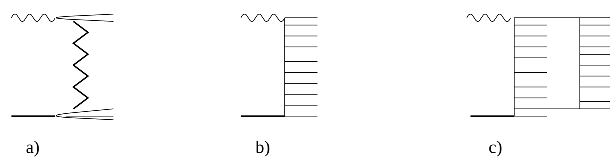

Figure 2: *Inelastic final states resulting from a) the diffractive cut describing low-mass diffraction, b) the one-pomeron cut, and c) the two-pomeron cut.*

the particle yield compared to the one-pomeron cut (in central pseudorapidity region, see Fig. 2), the inclusive inelastic charged particle cross section reads

$$\left.\frac{d\sigma_{\rm ch}}{d\eta}\right|_{\eta\approx 0} \sim 0\times(+1)\frac{dN_1}{d\eta} + 1\times(-4)\frac{dN_1}{d\eta} + 2\times(+2)\frac{dN_1}{d\eta} = 0 \qquad (1)$$

where the particle density in pseudorapidity of produced by a one-pomeron cut is denoted by $dN_1/d\eta$. Note that the cross section contribution of the two-pomeron graph vanishes. Analogously, the factorization violating contributions due to multi-pomeron exchange graphs cancel out in all orders. This means that only the one-pomeron graph determines the inclusive particle cross section in the central region (AGK cancellation). It can be shown that the same cancellation effects hold true also in the case of inclusive jet production.

In high-mass diffraction dissociation we have to consider only final state configurations with sufficiently large rapidity gaps. It is important to notice that all the configurations with more than one cut pomeron (multiple-interaction contributions, see Fig. 2 c)) are not considered for the diffractive cross section since in this case the rapidity gap of the diffractive process is filled by particles belonging to additional pomeron cuts. However, as shown above, these configurations are needed to cancel other negative terms implied by unitarity. Consequently, factorization is violated in diffraction dissociation since the cross section contributions of the higher-order multi-pomeron graphs do not vanish. For example, within the triple-pomeron approximation the diffractive cross section would grow with the energy like $\sigma_{\rm diff} \sim s^{2\Delta}$. The measured flat energy dependence is explained due to unitarity corrections: additional interactions produce particles filling the rapidity gap of the diffractive interaction. This can be effectively parametrized introducing a energy- and process-dependent *rapidity gap survival probability* $\langle |S|^2 \rangle$ [4].

2 A possible measurement of $\langle |S|^2 \rangle$

In the following we will discuss some consequences for particle production in high-mass photon dissociation at HERA. In comparison to hadron-hadron interactions, there are two important new effects to note: **(i)** the photon has a dual nature and can interact as a gauge boson (pointlike) or a hadron (resolved), and **(ii)** the photon has an additional degree of freedom, the photon virtuality. Both (i) and (ii) give a handle to suppress the relative size of the unitarity corrections (e.g. the relative size of the multi-pomeron graphs compared to the one-pomeron exchange) [5].

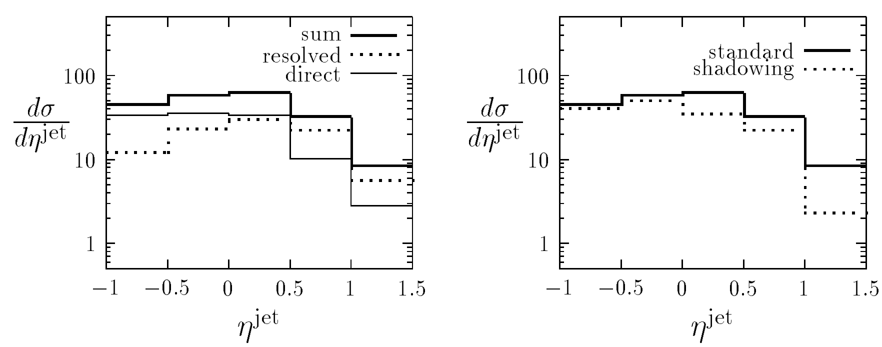

Figure 3: Differential single-inclusive jet cross section $E_\perp > 6$ GeV: a) breakdown in direct and resolved processes for $\langle |S_{\rm res}|^2 \rangle$ =1, b) cross sections for $\langle |S_{\rm res}|^2 \rangle$ =1 (standard) and $\langle |S_{\rm res}|^2 \rangle$ =0.5 (shadowing)

Using these effects, the rapidity gap survival probability can be determined experimentally as follows

(i) measurement of the diffractive structure function F_3^D in deep-inelastic photon-proton scattering

(ii) extraction of parton densities of the pomeron (gluon densities are determined from scaling violation effects *without* using photoproduction data)

(iii) application of these parton densities to the calculation of single-inclusive particle cross sections or jet cross sections in high-mass diffraction dissociation of real photons, comparison with measurements to determine $\langle |S_{\rm res}|^2 \rangle$.

In $\gamma^\star p$ scattering with not too small Q^2, multiple pomeron exchange contributions are suppressed at least by a factor $1/Q^2$ compared to the leading amplitude. Hence in diffractive DIS unitarity corrections are small and the measurement (i) provides the "true" parton density of the pomeron. However, in photoproduction unitarity effects (e.g. multiple-pomeron exchange contributions) are important. Furthermore the rapidity gap survival probability in hard diffraction differs significantly between direct and resolved photon interactions. In direct photon interactions, there is no hadronic remnant to allow for multiple interactions (e.g. two-pomeron exchange). Rapidity gap events with a resolved hard photon interaction are suppressed by a factor of about $2 \ldots 3$ compared to events with direct hard photon interactions. Having the possibility to distinguish in experiment between diffractive direct and resolved photoproduction in (iii) offers a unique means to check the predictions of multiple-interaction models and the concept of the rapidity gap survival probability. For example, we consider single-inclusive jet production applying the cut $\eta_{\max} < 1.5$ to select diffractive events in a simple "black–white" model where all resolved processes are treated as purely hadronic ones. The calculations were done using PHOJET [6,7]. In Fig. 3 a) the cross section is shown for direct and resolved events separately assuming $\langle |S_{\rm res}|^2 \rangle$ =1 for all processes. In Fig 3 b) the total jet cross section is shown for the case of $\langle |S_{\rm res}|^2 \rangle$ =1 and $\langle |S_{\rm res}|^2 \rangle$ =0.5. It should be emphasized that both curves differ in shape. Similar results are obtained in case of the transverse energy distribution of jets where resolved processes contribute mainly to the low-$E_\perp$ part.

3 On the determination of the diffractive cross section in $\gamma\gamma$ collisions

The diffractive contribution to the total $\gamma\gamma$ cross section is difficult to measure since the LEP detectors have only a very small acceptance for such events. On the other hand, the knowledge of the diffractive cross section is very important for many theoretical calculations as well as background estimations.

In analogy to the $\eta_{\max}$ cut applied by the HERA collaborations to identify diffractive events, a similar quantity can be defined for the case of $\gamma\gamma$ interactions [8]. Here one has to deal with the variation of the rapidity of the $\gamma\gamma$ system in the lab. frame. A possible way to define $\eta_{\max}$ in this case is to use a forward em. detector as a trigger for hadronic activity. In events with forward hadronic activity, $\eta_{\max}$ is then given by the pseudorapidity of the most-forward scattered particle seen in the central detector (for example, with a coverage of $|\eta| < 3$). This is illustrated in Fig. 4 a). The differential $\eta_{\max}$ cross section is shown in Fig. 4 b). Selecting events with a visible energy $W_{\rm vis} > 10$ GeV leads

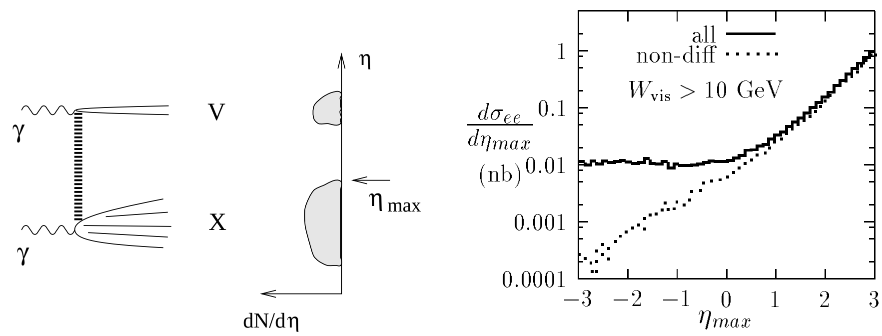

Figure 4: a) definition of the variable $\eta_{\rm max}$ in $\gamma\gamma$ collisions. b) ee cross section for all and for non-diffractive $\gamma\gamma$ at LEP2.

to an almost flat cross section for negative values of $\eta_{\rm max}$ clearly showing the diffractive contribution to the total $\gamma\gamma$ cross section. Of course, the method presented here can also be applied to $\gamma\gamma$ collisions at linear colliders.

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